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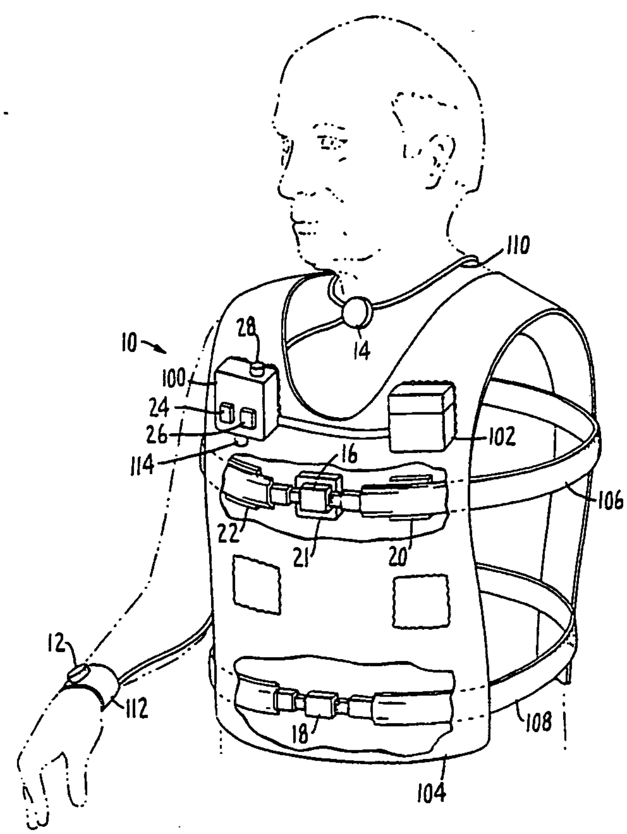
(54) Title: PORTABLE, MULTI-CHANNEL, PHYSIOLOGICAL DATA MONITORING SYSTEM

(57) Abstract

A portable unit (10) monitors physiological parameters using activity (12), vertical position (24) and rotational (26) sensors, a breath sound microphone (14), electrocardiogram electrodes (20), (21) and (22), and converts their analog signals into a serial stream of digital data using circuit pack (100). This circuit pack sends the transformed data to the battery/trasmitter pack (102) which transmits the data periodically. The plurality of sensors in vest (104) are worn by the patient with body straps (106) and (108). A position switch (114) and a nurse call button (28) are accessible to the patient. A base station (44) includes a receiver (42) which receives the transmitted data and reconverts it to a digital signal and a data processing unit (48) which records the data in memory (50).



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PORTABLE, MULTI-CHANNEL, PHYSIOLOGICAL DATA MONITORING SYSTEM

Background of the Invention

1. Field of the Invention

The present invention relates to medical monitoring systems and, in particular, to a highly portable, non-invasive, physiological data telemetry recording system for monitoring sleep disorders.

2. Discussion of the Prior Art

Conventional practice for diagnosing sleep disorders requires that the patient be admitted to a "sleep lab". Typically, these sleep labs are located at hospitals or clinics and consist of a special in-patient unit equipped with a complicated array of cumbersome polysomnograph equipment. The patient is required to sleep in the unit while being monitored by a combination of bulky, uncomfortable sensors which are attached to various parts of the body. Obviously, the accuracy of the data generated under these circumstances is suspect because of the unfamiliar environment and physically uncomfortable circumstances in which the data is taken.

To eliminate the problems associated with "sleep labs", solid-state portable physiological monitoring systems have been developed for use in the patient's own environment.

One such system is available from Vitalog Corporation. The Vitalog system is a portable microcomputer which monitors information from up to eight physiological sensors. This information is processed and stored in on-board, solid-state memory for subsequent retrieval or display by a separate computer system.

The Vitalog system contains an eight-channel analog-to-digital interface and an R-wave detector. The

multichannel A/D converter samples eight analog inputs. A one-channel motion sensor composed of an array of omnidirectional mercury tilt switches detects patient movement. A one-channel electrocardiogram (ECG) signal is monitored using three standard ECG electrode pads. The amplified ECG signal is connected to an A/D channel and also to the R-wave detection circuit. A temperature sensor array monitors three channels of temperature using standard probes. Either one or two channels of respiration may be monitored. One channel can be programmed to monitor a patient response button.

When the Vitalog system is activated, its ROM-based operating system continuously monitors the sensor inputs. After each programmed monitoring period, information relating to heart rate, physical activity and temperature is stored. A running mean of normal R-R intervals is calculated at the end of each heart beat. At the end of each monitoring period, the current mean is encoded into one of 16 levels (4 bits) and stored. A filtered output count from the motion sensor is accumulated and encoded into one of 8 levels (3 bits). Temperature information is encoded using a 3-bit tracking scheme.

The Vitalog system can store data from a minimum of 3600 epochs. Data compression is used to ensure that no memory is used when data is unchanging.

A fundamental shortcoming of the Vitalog system is that it lacks individual event resolution. That is, because data gathered over a full monitoring period must be stored in limited on-board memory for retrieval at the end of the monitoring period, the data must be compressed prior to storage. This requires pre-storage processing according to a predefined algorithm, further limiting the stored data characteristics to rigid

identifying and modifying signatures, thus reducing analytical flexibility.

Thus, while the Vitalog system provides a screening tool, it does not address the need for a low cost, reliable, portable physiological data recording system which provides high data resolution for a number of parameters over long periods of time.

Summary of the Invention

It is an object of the present invention to provide a low-cost, miniature, portable, physiological data monitoring system.

It is also an object of the present invention to provide a portable, physiological data monitoring system which will simultaneously monitor, transmit by radio and continuously record a virtually unlimited quantity of data relating to a plurality of physiological parameters.

It is a further object of the present invention to provide a physiological data recording system with high frequency data gathering capability for high individual event resolution.

These and other objects of the invention are accomplished by the physiological data monitoring system of the present invention which consists of a portable sensor unit which is worn by the patient to continuously gather and transmit data and a base station which stores the transmitted data for review and analysis.

The portable sensor unit includes a plurality of sensors, each of which monitors a physiological parameter and generates a corresponding electrical signal. In the preferred embodiment of the invention, the following parameters are monitored: left and right abdominal ECG, vertical position, rotational movement, patient activity level, breath sound, chest respiration

and abdominal respiration; a nurse call button is also provided. The signal from each sensor is converted to a serial stream of digital data which is transmitted in real time as a low level radio signal by a digital telemetry transmitter.

The system base station includes a digital telemetry receiver which picks up the transmitted radio signal and provides it as digital data to a processing system for storage. In addition to high capacity memory, the base station also includes a standard I/O port for communication with other systems for review and analysis of the data.

<u>Brief Description of the Drawings</u>

Figure 1 is a schematic block diagram illustrating the system of the present invention;

Figure 2 is an illustration of the sensor unit of the system of the present invention;

Figures 3A and 3B combine to provide a schematic circuit diagram illustrating the analog portion of the sensor unit circuit of the system of the present invention;

Figure 4 is a schematic circuit diagram illustrating the activity sensor portion of the sensing unit circuit of the system of the present invention;

Figures 5A and 5B combine to provide is a schematic circuit diagram illustrating the digital portion of the sensing unit circuit of the system of the present invention;

Figure 6 is a schematic diagram illustrating the circuitry of the telemetry transmitter used in the system of the present invention; and

Figure 7 is a schematic diagram illustrating the circuitry of the telemetry receiver used in the system of the present invention.

Detailed Description of a Preferred Embodiment

Fig. 1 shows a schematic block diagram of the monitoring system of the present invention.

A portable sensor unit 10, which is worn by the patient to be monitored, includes a number of sensors which continuously gather physiological data from the patient and generate corresponding electrical signals.

In the embodiment shown in Fig. 1, the physiologic data sensors include: an activity sensor 12, a breath-sound microphone 14, a chest respiration transducer 16, an abdominal respiration transducer 18, an oximeter 19, left and right electrocardiogram (ECG) electrodes 20 and 22, respectively, a vertical position sensor 24 and a rotational movement sensor 26. The sensor unit 10 also includes a manually operated, nurse call switch 28. The embodiment of the invention described herein also includes two spare sensor channels which could be used to monitor additional physiological parameters, but are presently used to provide warning signals indicating low battery power and an ECG "leads-off" condition, as described below.

The electrical signals generated by activity sensor 12, breath-sound microphone 14, the two respiration sensors 16 and 18 and oximeter 19 are analog signals which are provided to a multiplexer 30. Multiplexer 30 sequentially forwards these signals, together with the signals from the two spare channels, to an analog-to-digital converter 32 in response to clock signals provided by a system timer 34. The A/D converter 32 converts the analog input signal from the sensors to a binary data word which serves as the input to a serial encoder 36.

The signals from the left and right ECG electrodes 20 and 22 are provided to an ECG and R-wave detector 23.

The output of R-wave detector 23, which is representative of the patient's heart beat rate, is provided to a counter 25 which generates a 2-bit heart beat signal to interface latch 38. The signals from vertical position sensor 24 and rotational movement sensor 26 are provided to a priority encoder 27 which provides a 4-bit signal representative of these parameters to interface latch 38, the signal from the vertical position sensor 24 being given priority. Nurse call switch 28 provides a 1-bit "on-off" signal to latch 38.

The 8-bit output of interface latch 38 comprises 7 bits of data from its just-described associated sensors and an additional system synchronization bit, set to 1, to inform the base station 44 of the beginning of a transmission sequence. The 8-bit output of A/D converter 32 also includes 7 data bits from its associated channels, the eighth bit being always set to zero to distinguish it from the synchronization bit of the interface latch output.

Serial encoder 36 converts each of the 8-bit parallel digital signals from A/D converter 32 and interface latch 38 to a serial data stream. The serial data stream is then provided to a digital telemetry transmitter 40 which transmits the uncompressed data by low-power radio signals at one-half second intervals to a telemetry receiver 42 of portable base station 44.

Thus, the complete transmission sequence is composed of eight channels, each 8 data bits wide, as described above. Each channel is composed of 12 synchronization pulses, a 7-bit address which identifies the channel and the 8 data bits.

The power for the sensor unit 10 is provided by a battery unit 46, which comprises four AAAA size batteries of 0.3" thickness. Use of these "quad-A'

batteries allows the thickness of sensor unit 10 to be less than about 0.5 inches, making it relatively inobtrusive in comparison to prior art devices.

The radio signal received by telemetry receiver 42 is provided as a digital signal to CPU 48 which stores the data in memory 50 and/or communicates with additional peripheral devices via I/O port 58 for review and analysis of the data. The base station 44 also includes an LED display which verifies that data is being received and stored.

As shown in Fig. 2, sensor unit 10 includes a hybrid analog/digital circuit pack 100 which receives signals from the various sensors described above and provides these signals as a serial digital data stream to a second pack 102 which includes battery unit 46 and telemetry transmitter 40.

The circuit pack 100 and the battery/transmitter pack 102 are both attached to a body vest 104 by means of a Velcro® patch attached to the back of each unit 100, 102 and a corresponding patch attached to the vest 104. The vest 104 includes Velcro® patches for this purpose located both at the upper chest portion and at the abdominal portion so that the patient may attach the two packs 100 and 102 at the personally most comfortable location.

The hybrid circuit pack 100 receives the two respiration signals from two conventional respiration transducers 16 and 18 which are mounted around the patient's chest and abdomen, respectively. As shown in Figure 2, each of the chest and abdominal respiration transducers 16 and 18 is formed as part of a body strap 106 and 108, respectively, which fits around the patient's torso to position the transducer at the desired location.

Two ECG electrodes 20 and 22 are attached to the patient, one at each side of the patient's chest area, and connected by shielded leads to the hybrid circuit pack 100. A third ground ECG electrode 21 is attached to the patient between the other two. In the preferred embodiment, the three ECG electrodes 20, 21 and 22 are connected to the inner side of chest respiration strap 106.

An electret microphone 14 is located at the patient's supersternal notch by means of a throat collar 110. Microphone 14 monitors the patient's breath sound and transmits a representative signal to the hybrid circuit pack 100.

A vibration piezo transducer 12 mounted on the patient's wrist by means of a bracelet 112 also provides its signal to the hybrid circuit pack 100.

The hybrid pack 100 further includes two position sensors 24 and 26 which, in the preferred embodiment, are mercury switches which monitor rotational movement and vertical position, respectively. A position switch 114 mounted at the bottom of the hybrid circuit box is used to normalize the body position of the patient when the position switch 114 is pressed. That is, when the position switch 114 is pressed, the patient's position at that time is defined as being "nose up", i.e., the patent is on his back with his nose in the vertical position. A nurse call button 28 is located at the top of the hybrid circuit pack 100 and may be activated by the patient.

Figures 3A and 3B provide a detailed circuit schematic diagram of the analog portion of sensor unit 10.

As shown in Figure 3A, nodes N1 and N2 receive the left and right ECG signals, respectively, from left and right ECG electrodes 20 and 22 for the Heart Rate

portion of the circuit. Node N3 is connected to center ECG/ground electrode 21. The ECG inputs from nodes N1 and N2 are provided to components 50 and 52, respectively, which together with component 54 form an instrumentation amplifier with a gain of approximately 1000. Transistors Q2 and Q3 form a "leads-off" detector circuit, where the base/emitter junction of transistor Q2 forms a fourth diode with clamping diodes D2, D3 and D4. This "leads-off" detector circuit operates with an external bias such that the conducting path is either from node N1 to ground node N3 or from node N1 to node N2 with the ECG leads connected. With the leads off, the current from ECG electrode 20 which is connected to node N1, is provided to the base of transistor Q2. This turns on both transistor Q2 and transistor Q3 and provides a high level output at node N4. This output is provided to one of the unused transmission channels, as mentioned above, to indicate that an ECG lead is disconnected.

A gain block composed of instrumentation amplifier 56, together with its feedback component, form a limiting amplifier with amplitude and slew rate limiting. The output of instrumentation amplifier 56 is zeroed by an autonull amplifier 57 which assures that the output of instrumentation amplifier 56 is forced quiescently toward zero. The output of instrumentation amplifier 56 is provided to a high pass formed by capacitor C26 and resistor R52 and also to a band pass filter 58. The output of band pass filter 58 is provided to a resistor divider formed by resistors R56 and R57 to ground and also to resistor R61 which is an input of amplifier 64. Amplifier 62 and its feedback circuitry receive the information from the output of amplifier 58 and capture that peak voltage onto capacitor C32. The voltage of capacitor C32 is then

applied to the positive input of amplifier 64, the other input to amplifier 64 being provided through previously-mentioned resistor R61. The output of amplifier 64 through polarity blocking diode D8 forms a negative going waveform, which is the difference between the peak voltage applied at the positive input to amplifier 64 and the output of amplifier 58, and is applied through capacitor C34 to a comparator 60, the threshold of which is set by a divider provided by resistor R67 through resistor R66 to ground. Resistors R62 and R63 form positive feedback, or hysteresis, to assure clean switching of the output. The output of comparator 60 is then provided to node N5 which is the output pin of the Heart Rate, or ECG, circuit and the input to heart rate counter 25 shown in Figure 1. The total of this aforedescribed circuitry forms R-wave detector 23 which provides one pulse per peak electrical QRS complex.

Referring now to the Breadth Sound section of Figure 3B, resistor R1, capacitor C1 and resistor R70 form a bypass and bias network for electret microphone 14, the network then being connected back to node N6 of the circuit. The network around amplifier 66 forms a gain block and band pass filter which feeds a second gain block and band pass filter 68. The band pass of this network is approximately 300-900 Hz, while the network gain is approximately 500. The output of filter 68 is biased by resistor R5 toward the negative rail to allow full scale presentation of the breadth sound signal amplitude. This output is applied to resistor R7 and through diode D1. The peak waveform is captured across capacitor C8 to the negative rail with the discharge path through resistor R8 and parallel with capacitor C8 to output node N7 which is an input to multiplexer 30.

Referring now to Figure 4, which shows the Activity portion of the circuit, the signal from the activity transducer 12 is received at node N8, provided to amplifier and low pass filter 70 and then to tracking comparator 72. The output of tracking comparator 72 is provided to non-retriggerable one-shot 74 which clocks out a digital signal to counter 76. The output of counter 76 is provided to a digital-to-analog converter 78, the output node N9 of which serves as an input to multiplexer 30. The counter 76 is reset to the 0 position by non-retriggerable one-shot 79 which is triggered by the falling edge of the transmitter enable signal, as described below.

Referring now to the Power Supply section of Figure 3A, a 1.2 reference voltage 80 is provided to the negative input of amplifier 82. Transistor Q1, which is a series pass element, is operated in the inverted mode for low dropout characteristic. The feedback path for the regulator is through resistors R71 and R72 where nodes N10 and N11 are tied together for this application. Capacitor C36 forms an output compensation network to provide stability, since transistor Q1 is operating as a gain stage. Resistor R15 provides start-up current for the regulator.

Referring now to the Respiration section of Figure 3B, the signals from both the abdominal and the chest transducers 18 and 16 are received at nodes N12 and N13, respectively. The signal received at node N12 is applied to capacitor C13 and to a boot strap amplifier 86 formed by booting resistors R17 and R19 to ground, where resistor R69 is brought off the center of this bootstrap configuration and provides a thousand megohm equivalent inputted impedance. The output of bootstrap amplifier 86 is applied through a gain block 88, the gain of which is set by resistors R22 and R24. The

output of amplifier 88 is provided past one diode drop and again is reduced by the forward conductivity of diode D10, putting resistor R76 in parallel with resistor R24. Amplifier 90 and its associated circuitry provide an autonull loop for the output of bootstrap amplifier 88 which is sensed through resistor 26. The output of amplifier 90 is coupled back into amplifier 88 through resistor R25. The quiescent voltage of amplifier 88 is set by resistor divider R32 and R33 and is approximately -1.1 volts. Thus, the output of the abdominal transducer portion of the circuit is provided at node N14.

The chest transducer signal received at node N13 is similarly processed via amplifiers 86', 88' and 90' to provide a chest transducer output at node N15.

Referring now to the digital portion of the sensor unit circuitry shown in Figures 5A and 5B, the output of the Heart Rate circuitry of Figure 3A is provided to node N16 and passes through diode D1 which shifts the level from positive to negative voltage. The logic requires only a positive to ground; therefore, diode D1 blocks the negative voltage and 4-bit counter 25 stores the heart rate count. This information is then provided to interface latch 38 as a 2-bit signal every one-half second during transmission.

A low voltage battery detector 94 provides its output on node N17 to one of the otherwise unused analog channels mentioned above. A low battery is, therefore, detected at base station 44.

A voltage converter 96 receives the voltage from the battery unit 46 and converts it to a negative voltage output. Therefore, node N18 of the digital hybrid circuit is the -4.5 voltage negative power supply point for the system.

Priority encoder 27 receives the signals from both position sensors 24 and 26, with the vertical position transducer receiving highest priority, and encodes it into four bits of binary weighted code. Nodes N19-N27 are the input pins from the position transducers.

Node N28 of the digital hybrid circuit switches the transmitter power supply and is gated from the output of the system enable timer 34. Thus, the signal at node N28 resets the one-shot 79 of the activity circuit.

Serial encoder 36 receives parallel digital data presented on its input pins and applies a serial output to the channel address at nodes 29-35, bringing these nodes either to ground or to the positive rail. Serial encoder 36 also produces an 8-bit serial data stream at node N36 which modulates transmitter 40.

Interface latch 38 switches in the digital information from its associated sensors during the digital channel transmission.

A/D converter 32 receives the output of analog multiplexer 30 and, upon command, digitizes each of the analog levels presented by multiplexer 30.

Transistors Q4 and Q5 are gated power supply devices which provide power to A/D converter 32.

Figure 6 shows a detailed schematic circuit diagram of the digital telemetry transmitter 40.

As shown in Figure 6, the serial data transmissions from encoder 36 are first modulated by a programmable data coder and then provided to a low pass filter. The filtered signals are then provided to a modulator, the output of which is forwarded to an oscillating section of the transmitter circuitry, the frequency determining element of which, i.e., crystal C100, has a resonant frequency of approximately 20 MHz. The outputs of th ecrystal C100 are amplified before exiting the oscillator section of the circuit and then forwarded to

a first frequency tripler which triples the third harmonic of the oscillator output. The output of the first frequency tripler section is provided to a second frequency tripler section which generates the ninth harmonic of the oscillator output. The frequency of the output of the second tripler section is in the range of 180-212 MHz, which is known as the medical band. The outputs of the second tripler section are forwarded to the antenna elements of the transmitter 40 for transmission to the base station 44.

Figure 7 shows a detailed schematic circuit diagram of the digital telemetry receiver 42. The signals transmitted from the transmitter 40 are received by the antenna elements of receiver unit 42. The signals received by the antenna elements are forwarded to an amplifier and summer network. The outputs of this network are forwarded to an RF amplifier, a mixer, and an amplifier and filter section. The output of the amplifier and filter section is provided to a serial decoder 47 which outputs an 8-bit digitized audio signal that is provided to CPU 48 for either storage in memory 50 or transmission through I/O port 58 to diagnostic equipment for analysis and review.

In the preferred embodiment, CPU 48 is an Hitachi 64180 microprocessor which directly addresses 512K of RAM and has a built-in R232C I/O port.

Data valid display 52 is an LED which is driven from a one-shot which is triggered by the data-valid port of serial decoder 47.

It should be understood that various alternatives to the embodiment shown herein may be employed in practicing the present invention. It is intended that the following claims define the invention, and that the structure within the scope of these claims and their equivalents be covered thereby.

Claims

What is claimed is:

1. A data monitoring system for gathering physiological data from a patient, the system comprising:

a portable sensor unit which is worn by the patient and which includes

(i) a plurality of sensors attached to the patient's body, each of which monitors a physiological parameter and generates an electrical signal corresponding thereto;

(ii) means responsive to such signals for converting each such signal to a serial stream of digital data; and

(iii) a transmitter which periodically receives each such digital data stream and transmits it as a radio signal; and

a base station which includes

(i) a receiver which receives the radio signal and converts it to a digital signal; and

(ii) a data processing unit which receives the data signal and records it

such that the data monitoring system simultaneously monitors, transmits by radio and records data relating to each physiological parameter.

2. A data monitoring system as in claim 1 wherein the plurality of physiological parameters includes patient heart rate.

3. A data monitoring system as in claim 2 wherein the plurality of physiological parameters further includes patient respiration.

4. A data monitoring system as in claim 3 wherein the plurality of physiological parameters further includes patient breath sound.

5. A data monitoring system as in claim 4 wherein the system also monitors patient vertical position.

6. A data monitoring system as in claim 5 wherein the system also monitors patient rotational movement.

7. A data monitoring system as in claim 6 wherein the system also monitors patient activity level.

8. A data monitoring system as in claim 7 wherein the system further includes a nurse call button.

9. A data monitoring system as in claim 1 wherein the system transmits data at one-half second intervals.

10. A data monitoring system as in claim 1 wherein the sensor unit includes four AAAA batteries which provide power for the sensor unit.

11. A data monitoring system as in claim 10 wherein the sensor unit is less than about 0.5 inches thick.

12. A system for gathering physiological data from a patient, the system comprising:

a body vest which is worn by the patient, the body vest having a sensor unit attached thereto;

a plurality of physiological sensors attached to the patient's body, each of which monitors a

physiological parameter and provides an electrical signal corresponding thereto to the sensor unit;

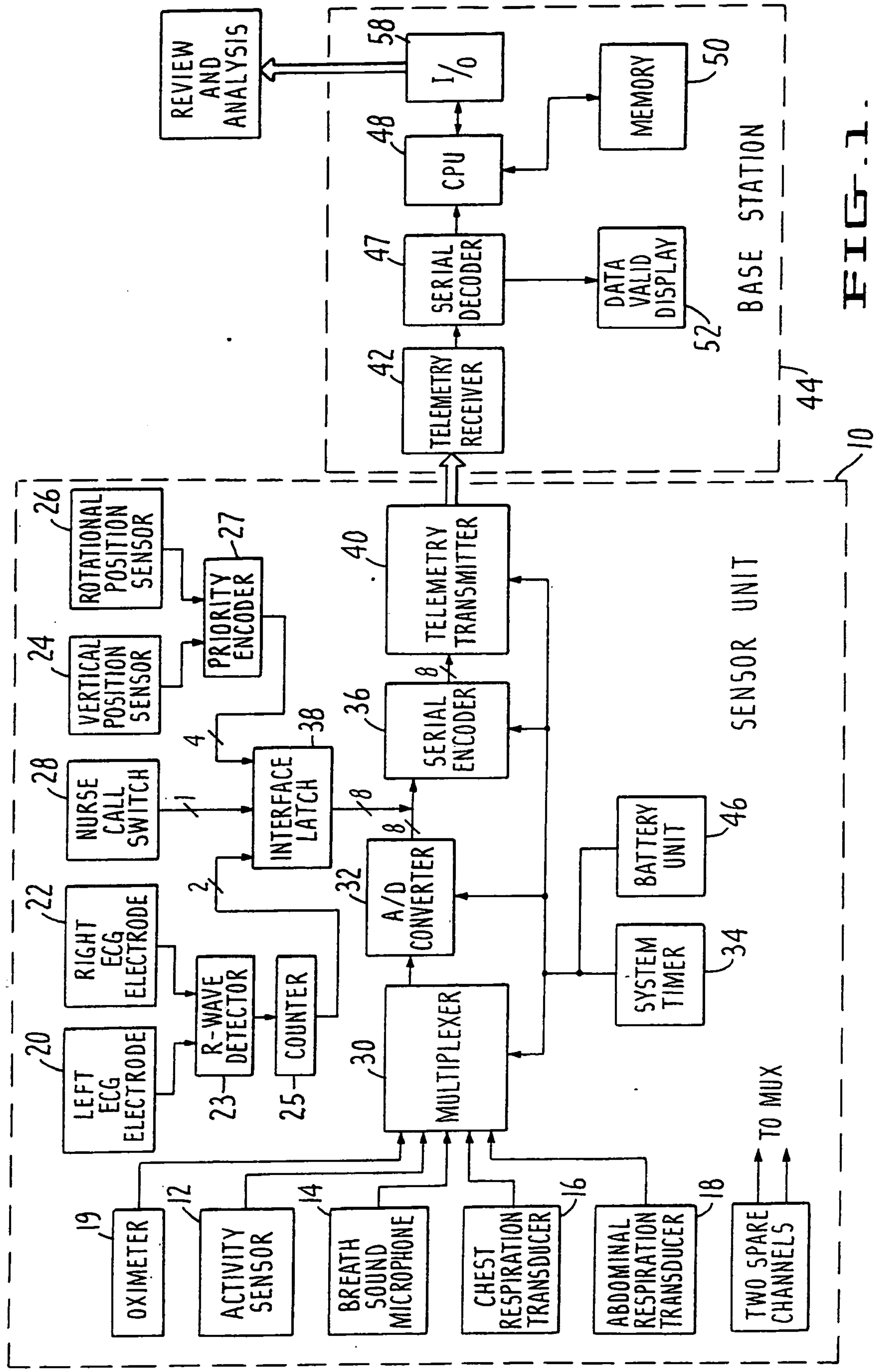
circuit means included within the sensor unit for converting the signals received from the sensors to a serial stream of digital data;

a transmitter included within the sensor unit to receive the serial stream of digital data and periodically transmit the data as a radio signal; and

a base station which includes a receiver which receives the radio signal and reconverts it to the digital data and memory for storing the data.

13. A system as in claim 12 wherein the transmitted data is uncompressed.

14. A system as in claim 12 wherein the data is transmitted at one-half second intervals.


REVIEW AND ANALYSIS
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MEMORY
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SERIAL DECODER
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DATA VALID DISPLAY
52
TELEMETRY RECEIVER
42
BASE STATION
44
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ROTATIONAL POSITION SENSOR
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PRIORITY ENCODER
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VERTICAL POSITION SENSOR
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TELEMETRY TRANSMITTER
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NURSE CALL SWITCH
28
INTERFACE LATCH
38
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RIGHT ECG ELECTRODE
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A/D CONVERTER
32
BATTERY UNIT
46
LEFT ECG ELECTRODE
20
R-WAVE DETECTOR
23
COUNTER
25
MULTIPLEXER
30
SYSTEM TIMER
34
OXIMETER
19
ACTIVITY SENSOR
12
BREATH SOUND MICROPHONE
14
CHEST RESPIRATION TRANSDUCER
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ABDOMINAL RESPIRATION TRANSDUCER
18
TWO SPARE CHANNELS
TO MUX
1
2
4
8

FIG. 1.

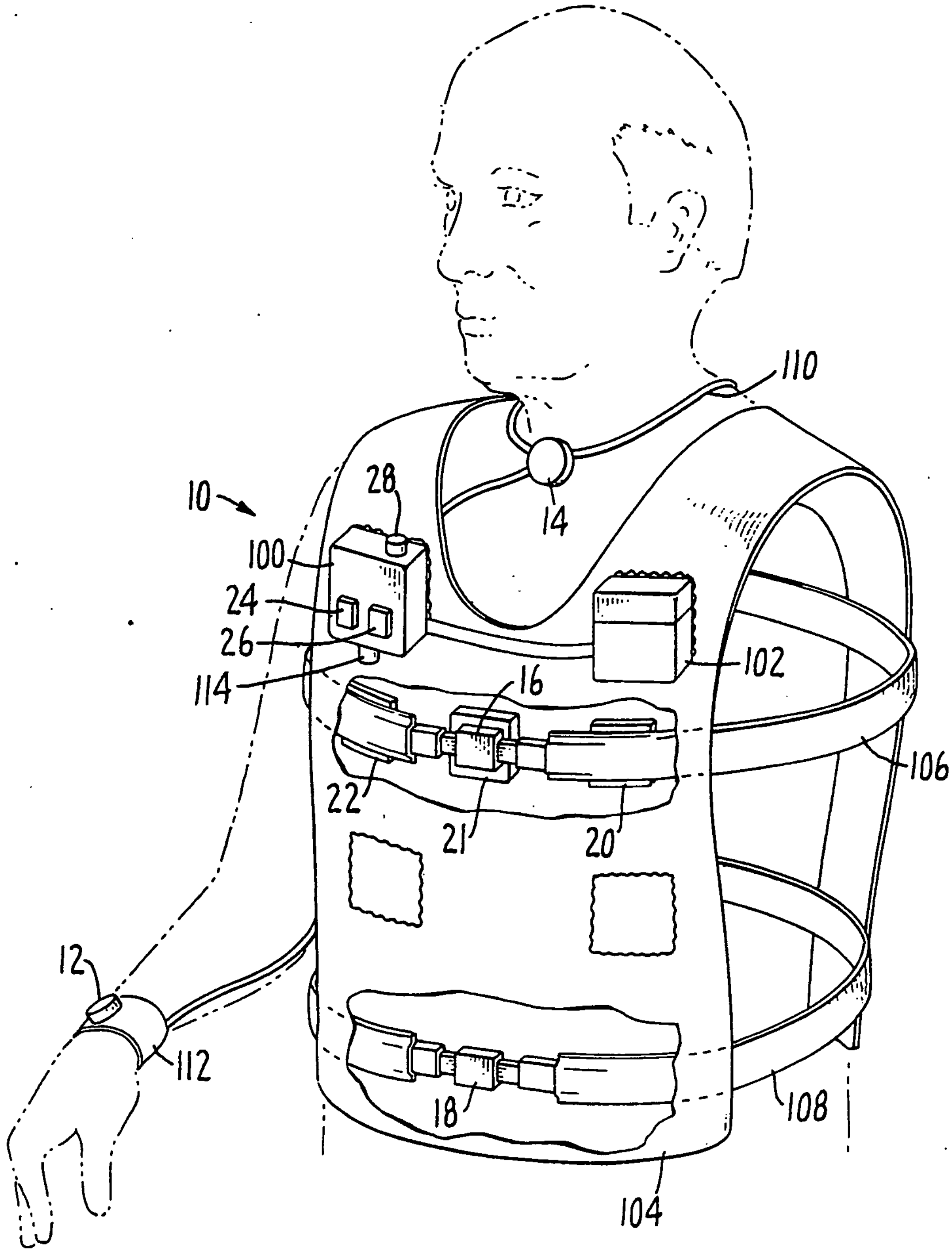

FIG. 2.

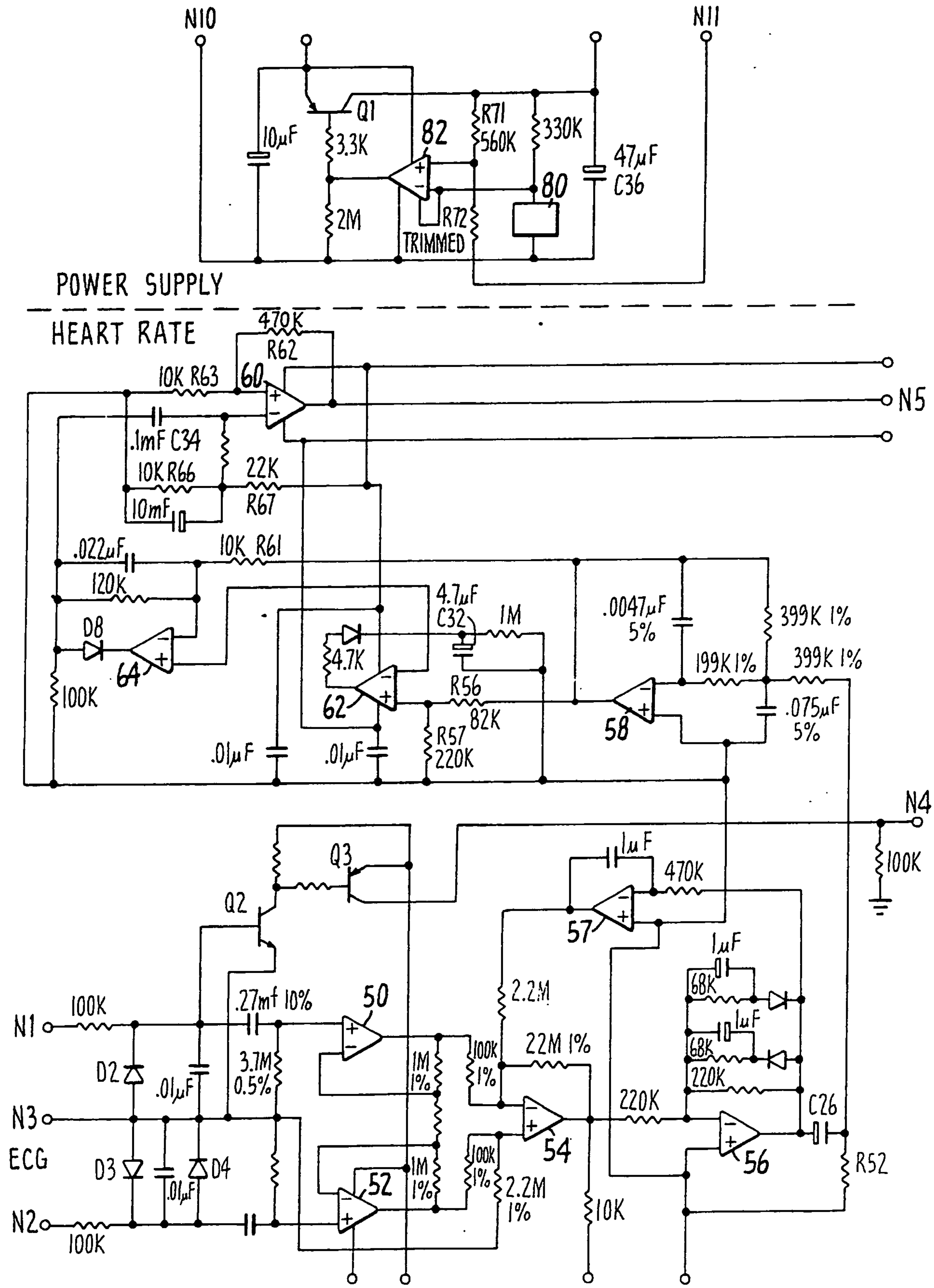
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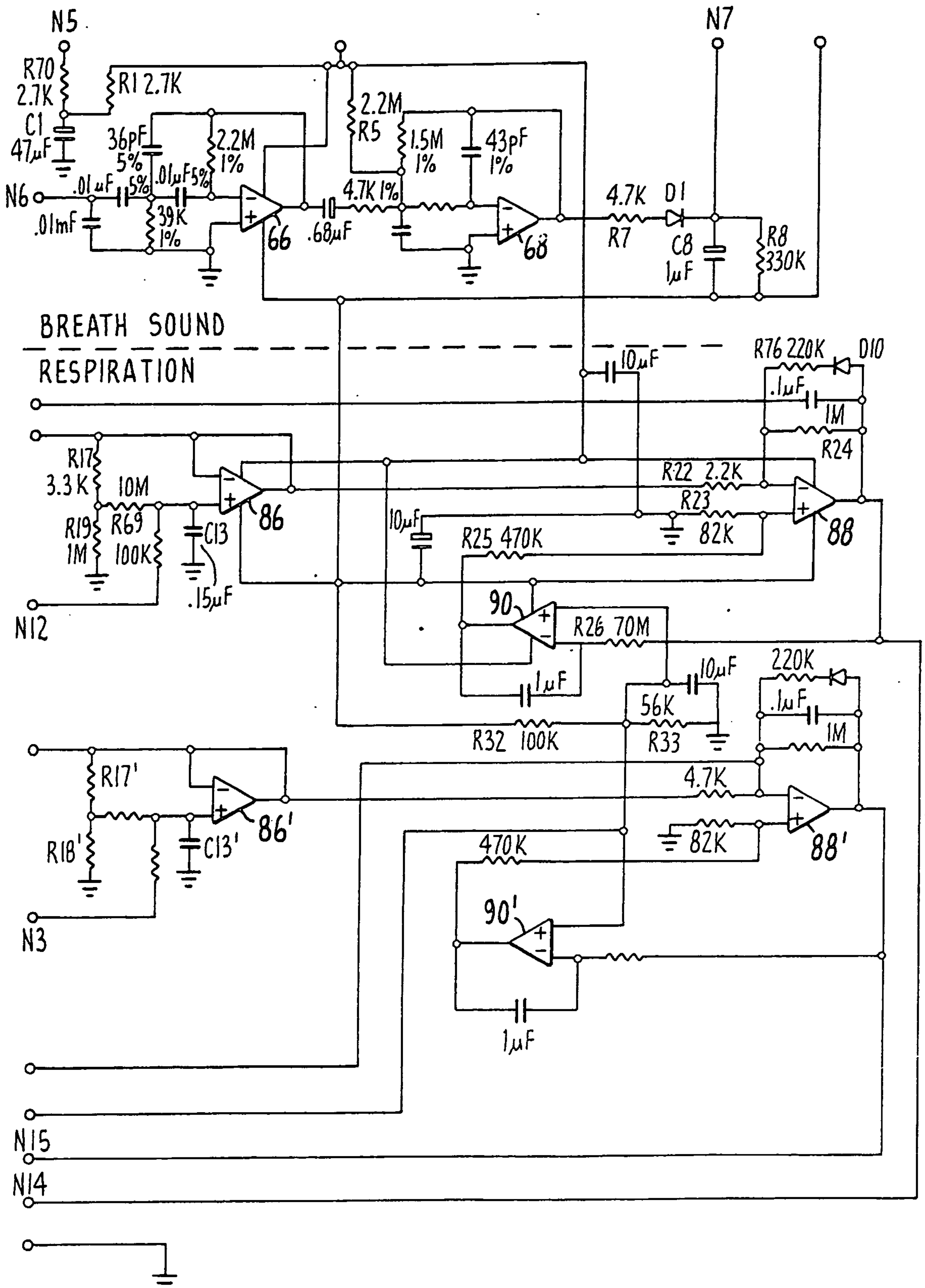
FIG. 3A.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R25 470K
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R32 100K
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N3
N15
N14

FIG. 3B.

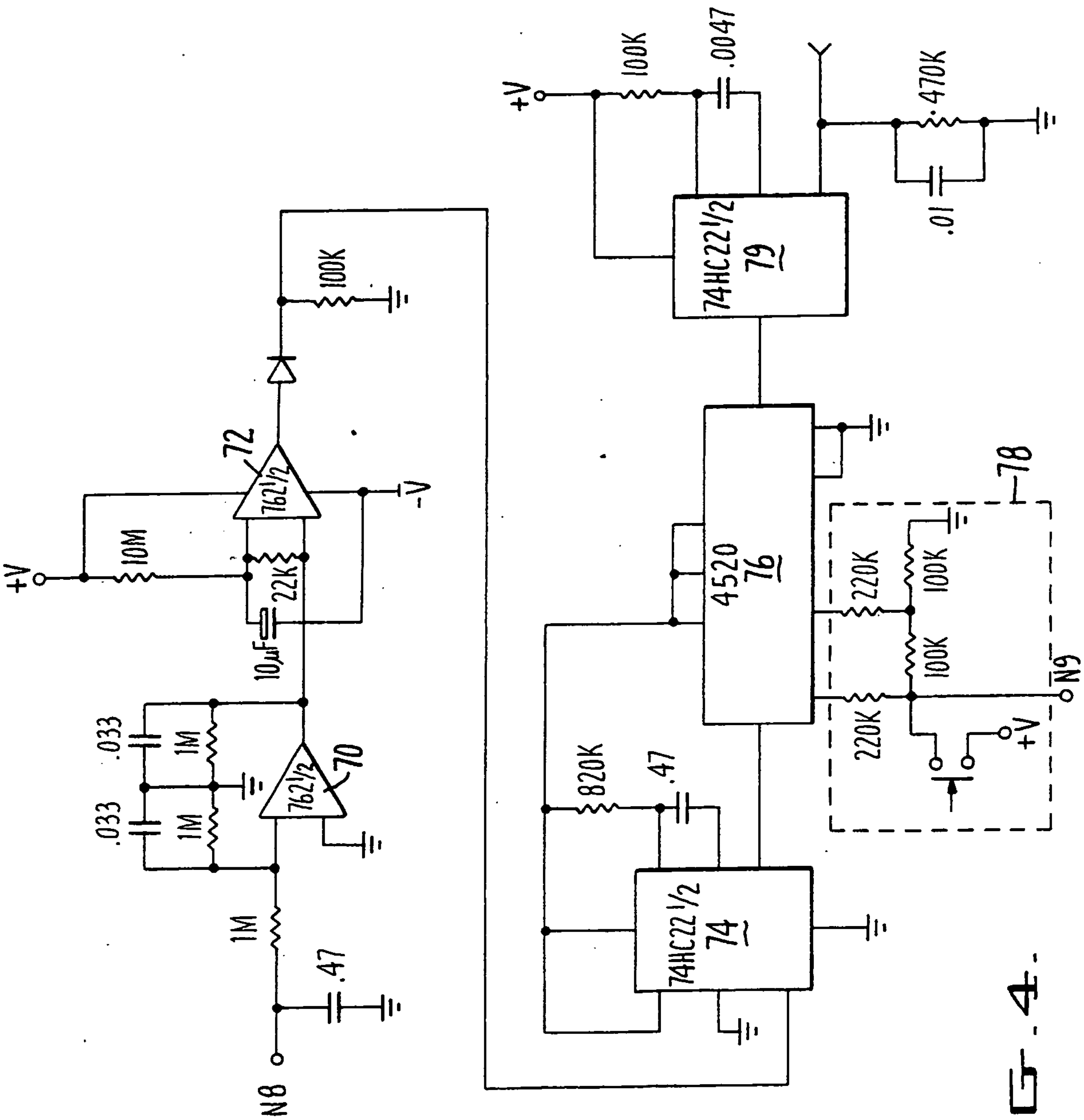
N8
.47
1M
.033
.033
1M
1M
762 1/2
70
10µF
22K
+V
10M
762 1/2
72
-V
100K
+V
100K
.0047
74HC22 1/2
79
470K
.01
4520
76
78
220K
100K
220K
100K
N9
+V
820K
.47
74HC22 1/2
74

FIG. 4

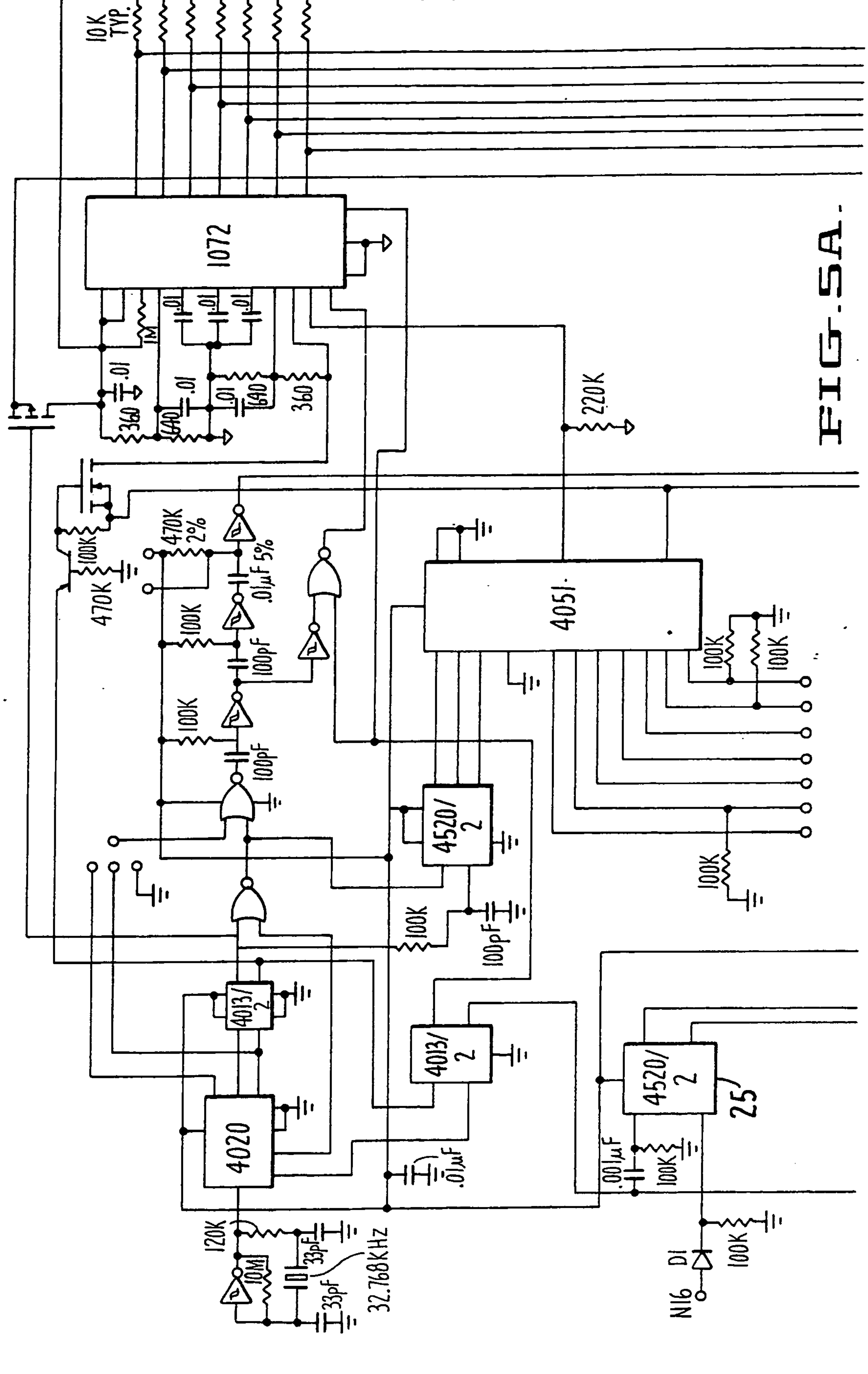
10K TYP.
1072
1M
.01
360
640
220K
470K 2%
.01μF 5%
100K
100pF
470K
4051
4520/2
4013/2
4020
120K
10M
33pF
32.768KHz
.01μF
.001μF
D1
N16
25

FIG. 5A.

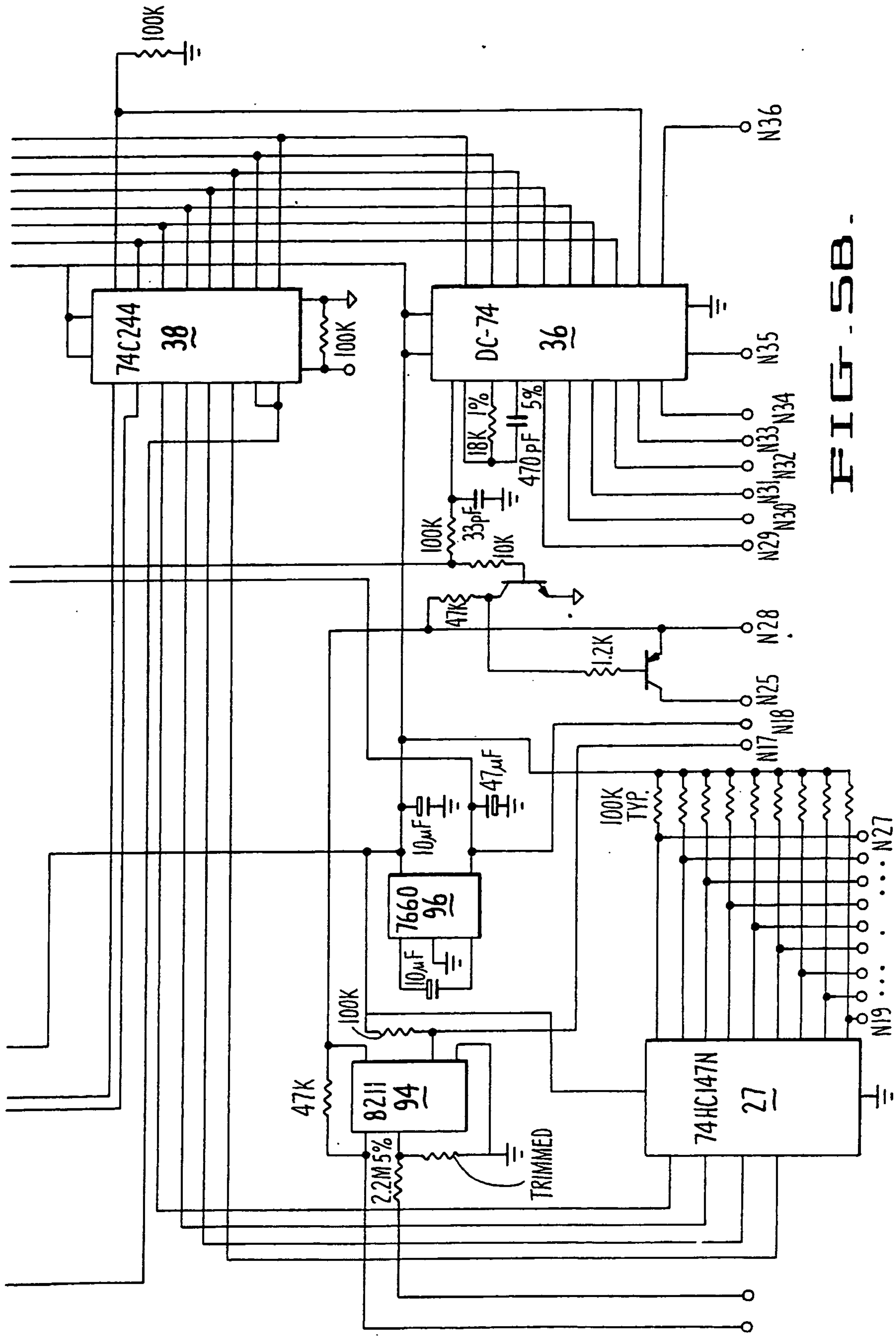
74C244
38
DC-74
36
7660
96
8211
94
74HC147N
27
100K
18K 1%
470pF 5%
33pF
10K
47K
1.2K
47μF
10μF
100K TYP.
2.2M 5%
TRIMMED
N36
N35
N34
N33
N32
N31
N30
N29
N28
N25
N18
N17
N27
N19

FIG. 5B.

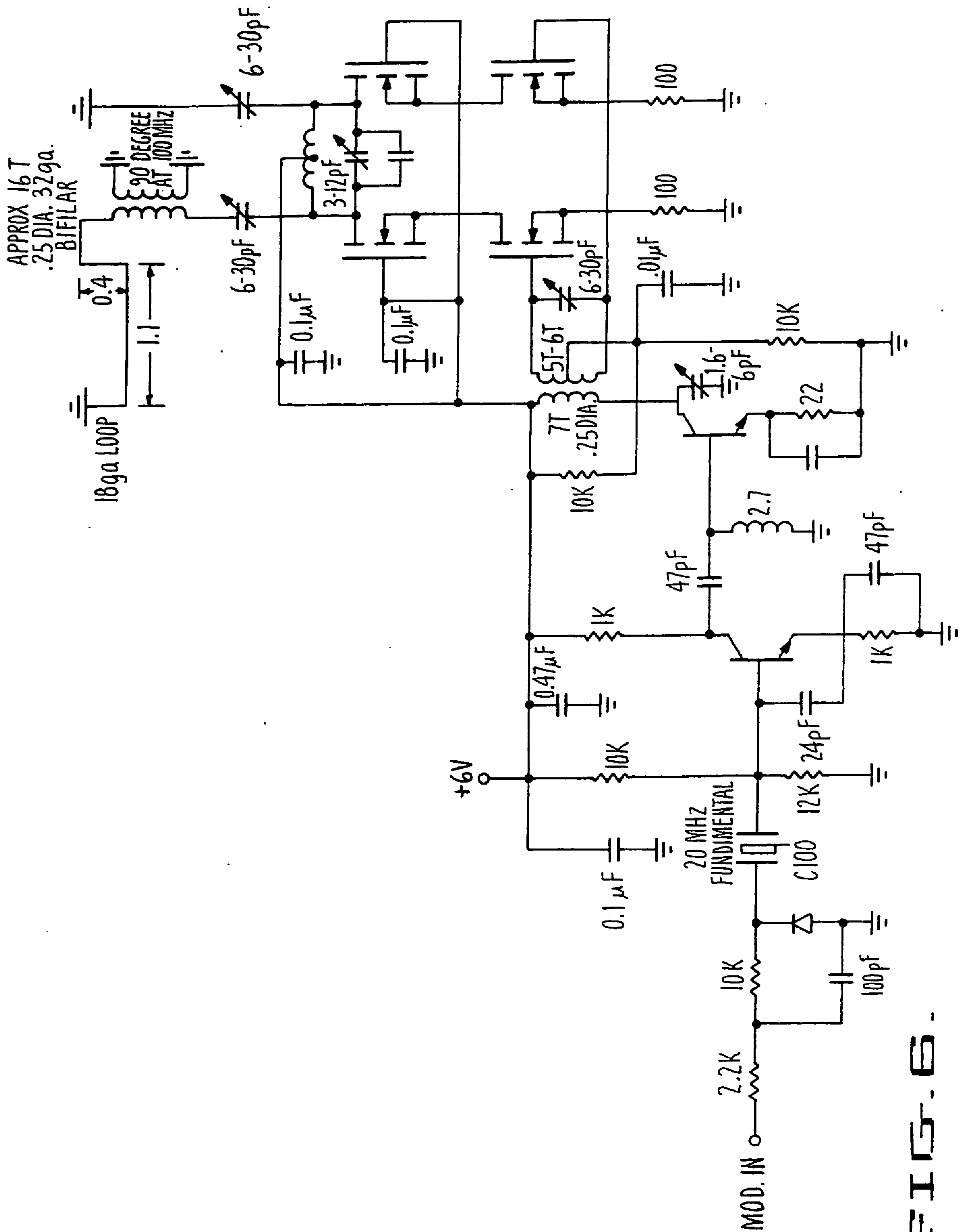
APPROX 16 T
.25 DIA. 32ga.
BIFILAR
90 DEGREE
AT 100 MHz
6-30pF
6-30pF
3-12pF
0.4
1.1
18ga LOOP
0.1μF
0.1μF
100
100
6-30pF
.01μF
5T-6T
7T
.25DIA
10K
10K
1.6-6pF
22
2.7
47pF
47pF
1K
1K
0.47μF
+6V
10K
24pF
12K
20 MHz
FUNDIMENTAL
C100
0.1 μF
10K
100pF
2.2K
MOD. IN

FIG. 6.

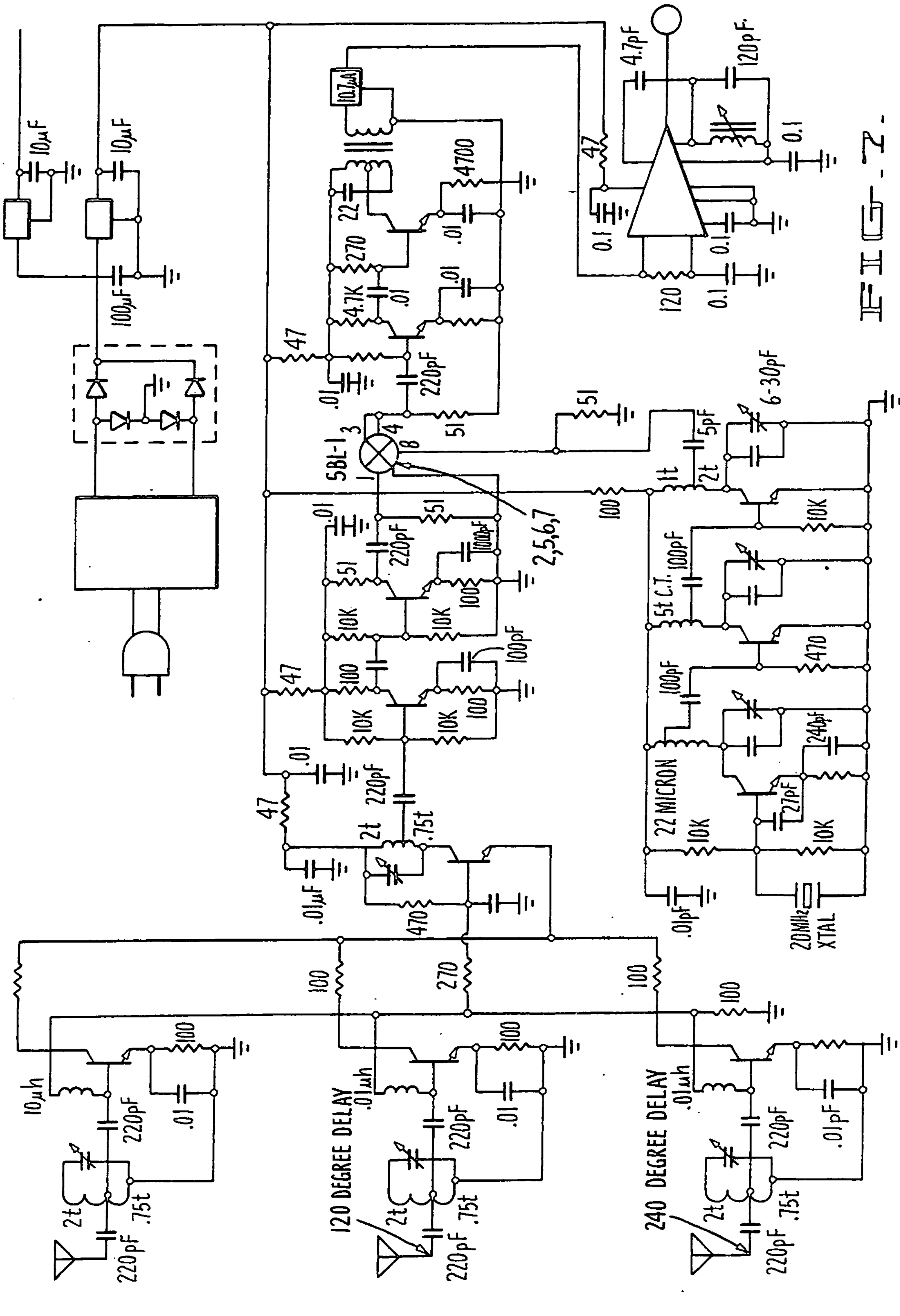
120 DEGREE DELAY
240 DEGREE DELAY
22 MICRON
20MHz XTAL
SBL-1
2,5,6,7
10.7 MHz

FIG. 7

INTERNATIONAL SEARCH REPORT

International Application No PCT/US87/02402

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (4): A61B 5/10 U.S. Cl. 128/668

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	Class 128, subclasses 668,671,774,782,903

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
Y	US, A, 3,815,109, CARRAWAY ET AL., 04 June 1974, See Col. 2, Col. 5, lines 63-65, Col. 7, lines 15-35	1-14
Y	Medical Research Engineering, Vol. 13, No. 2, April 1980, David Foster et al., "Telemetry Instrumentation for Kinesiologic Studies of Knee Motion", pages 17-21, See "Introduction", Col. 1, lines 1-10	5
Y	IEEE Transactions on Biomedical Engineering March 1976, Richard McPartland, "Activity Sensors for Use in Psychiatric Evaluation", pages 175-178. Page 175, Col. 2, lines 5-13	5-7

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
01 November 1987	04 DEC 1987
International Searching Authority [1]	**Signature of Authorized Officer [20]**
ISA/US	G. Manuel G. Manuel

Form PCT/ISA/210 (second sheet) (May 1986)